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# Automated reduction the speckle noise of the panoramic ultrasound images of Muscles and Tendons

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**Abstract.** Removing or reducing speckle noise is one of the main goals to ensure high quality panoramic ultrasound images of muscles and tendons. The presence of noise in the ultrasound image adds a difficulty in the interpretation of the image by clinicians and researchers. In this work, non-linear filter (local adaptive median filter (LAMF1)) has been developed to do a precise detection for speckle noise pixels and reduce its impact on the ultrasound images. It has been applied on three different types of ultrasound images: Based on using set of assessment metrics: Speckle Suppression Index (SSI), Speckle Suppression Mean Preservation Index (SMPI), Enhanced Edge Index (EEI) and Mean Preservation Speckle Suppression Index (MPSSI), the new local adaptive median filter (LAMF2) has been compared to LAMF1 and Anisotropic Diffusion Filter (ADF). The performance of developed filter (LAMF2) outperformed the performance of LAMF1 as follows: SSI (3%), SMPI (4.79%), EEI (3.7%) and MPSSI (40%). Besides that, ADF has a high level of SSI, SMPI and MPSSI compared to new filter (LAMF2). However, ADF reported better numerical evaluations (EEI) than LAMF2. It is possible to obtain further performance improvements by combining characteristics of both filters (LAMF2 and ADF).

**Keywords.** Speckle Noise Image Enhancement, Non linear filters, Speckle Noise Assessment Metrics and Musculoskeletal Ultrasound Imaging.

## 1. Introduction

Musculoskeletal Image quality of ultrasound images is affected by the presence of noises. Image noises ruin the fine details of the ultrasound image and effects on the image quality significantly. There are different kinds of noises in the medical images such as impulse noises, Gaussian noises and speckle noises [1]. Impulse and Gaussian noises are additive noises, while speckle noise is a multiplicative noise. The main difference between additive and multiplicative noises is that additive noises do not change the intensity of the main signal, therefore; it is possible to address it using linear filtering techniques. On the other hand, multiplicative noises cannot be dealt with using linear filtering techniques because of their complex structure which is due to the interference between grey level intensities of the noises and the original image [2].



Speckle noise is the dominant noise of the ultrasound images and Synthetic Aperture Radar (SAR) images. Speckle noise occurs due to coherent acquisition imaging systems. This coherence produces a complex form of noise (speckle noise) which corrupts the quality of images. Furthermore, Speckle noise reduction is usually involved as the image pre-processing step in some of the computer vision applications such as edge detection and image analysis [3], [4]. The presence of this kind of noise could hold up the execution of these applications. Obviously, the highest level of image quality could be achieved by using the best available devices; but it is also possible to get this level using the automated non-linear filters and improving the main factors which effect on the image quality.

One of the common filters is Anisotropic Diffusion Filter (ADF). ADF is an adaptive technique, which was used and applied successfully in the SAR image filtering [5], [6], then was applied to the ultrasound images such as kidney and heart ultrasound images [7], [8], liver ultrasound images [9], ultrasound images of the shoulder [10], of the hand [4] and other medical images [11], [12]. Another spatial filter in image processing is Local Adaptive Median Filter (LAMF) [13]. LAMF attains a good outcome in improving the image appearance of Synthetic Aperture Radar (SAR) images. It is performed according to the local evaluation of the statistical properties of the image (mean and standard deviation). Although speckle noise was tracked and detected automatically, it did not have enough ability to recognize most of the changes in grey level intensities that is created from coherence noises. Entropy is a powerful metric to evaluate the variation in frequency of grey level intensities and this tool can detect vague information from image details. A high score of the entropy indicates a high level of variation in grey level frequencies [14]. Therefore, entropy measurement is a promising approach to identify vague patterns in the image. In this work, we proposed an algorithm for overcoming this limitation by modification of Local Adaptive Median Filter (LAMF). This contribution aims to highlight the use of modified local adaptive median filter to reduce speckle noise in the musculoskeletal ultrasound image and compare it with the performance of Anisotropic Diffusion Filter.

The rest of this paper is organized as follows. related studies are introduced in the same section. Section II describes the methodology which describes the proposed algorithm, and Section III addresses implementation details. and results Section IV discusses experimental results. Finally, Section presents main conclusions and future work of the paper.

### 1.1. Related studies

#### A. Anisotropic Diffusion Filter (ADF)

One of the standard methods that have been utilized in reducing speckle noise in the ultrasound imaging is anisotropic diffusion filter. There are some applications in the ultrasound images [4], [7-11]. The key aspect of diffusion has been acquired from standard heat diffusion; if the diffusion expands in all directions, in this case, diffusion is called isotropic diffusion. Since this kind of diffusion has lack of clarity in defining an edge and spread in all directions without concerning on the edge preservation. Anisotropic diffusion is concerned with edge preservation because it concentrates on the direction to maintain edges. It happens by adding gradients of grey level intensity to the diffusion equation, as illustrated in equation (1).

$$(1) \quad \frac{d(X(i,j,t))}{dt} = \text{div}[g(|\nabla X(i,j,t)|) \cdot \nabla X(i,j,t)]$$

Where  $\nabla X(i,j,t)$  is the image gradient,  $t$  is time parameter and  $g(|\nabla X(i,j,t)|)$  controls the edge direction, image gradients illustrate the directional change of the grey level intensities. This helps in the detection and preservation of the image edges. It means, it is likely to reduce speckle noise and preserve firm edges. Perona and Malik introduced two different functions of diffusion [15], [16]; see equation (2) and equation (3).

$$(2) \quad F_1(p) = e^{\left(-\left(\frac{\|\nabla X\|}{k}\right)^2\right)}$$

are utilised in the evaluations.

$$(3) \quad F_2(p) = \frac{1}{1 + \left(\frac{\|\nabla X\|}{k}\right)^2}$$

Where  $k$  is the controlled factor on the gradient of the edge sensitivity. The first equation shows high contrast edges over low contrast edges, while the second equation illustrates a wider homogenous region over the small one.

### B. No-reference assessment metrics of speckle noise reduction

There are four metrics that were used in the performance assessment of speckle noise reduction in the resultant image. The reason for using these metrics is the difficulty of obtaining a reference image of musculoskeletal ultrasound that is entirely free from speckle noise. These metrics are employed without needing to the ground truth image; therefore, these metrics are the best choice for performance assessment after reducing speckle noise. The first metric is Speckle Suppressions Index (SSI), which can be calculated using equation (4):

$$(4) \quad SSI = \frac{\sqrt{\text{var}(R)} \cdot \text{mean}(I)}{\text{mean}(R) \cdot \sqrt{\text{var}(I)}}$$

Where  $R$  is the resulting image after filtering,  $I$  is the input image with speckle noise, var represents the variance and mean the average of the grey level intensity of the image. The variance of filtered image had to be less than input image due to speckle noise reduction; therefore, based on equation (8), small value of SSI indicates a high level of the speckle noise reduction in the image [17]. It is dependent on the ability to have a filter satisfying a mean-preservation property. Therefore, Shamsoddini addressed this problem by introducing a new metric, Speckle Suppression Mean Preservation Index (SMPI), which is evaluated using equation (5), [18].

$$(5) \quad SMPI = (1 + |\text{mean}(I) - \text{mean}(R)|) \cdot \frac{\sqrt{\text{var}(R)}}{\sqrt{\text{var}(I)}}$$

However, Dellepiane suggested another metric because SMPI has a limitation which relates to normalisation. It is the Mean Preservation Speckle Suppression Index (MPSSI) [19].

$$(6) \quad MPSSI = \left| 1 - \frac{\text{mean}(R)}{\text{mean}(I)} \right| \cdot \frac{\sqrt{\text{var}(R)}}{\sqrt{\text{var}(I)}}$$

Low score of these three metrics (SSI, SMPI and MPSSI) indicates a high level of speckle noise reduction in the output image. The last metric in the assessment of speckle noise reduction package is Enhanced Edge Index (EEI) [20]. Equation (7) illustrates how can carry out this metric based on input and filtered image

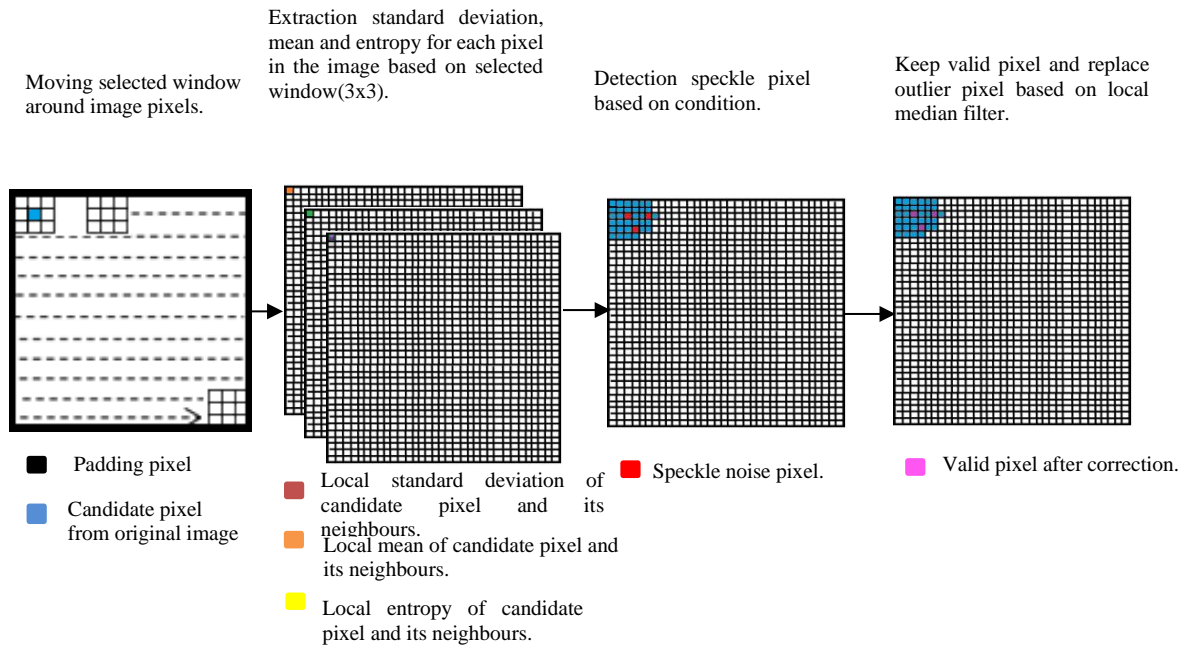
$$(7) \quad EEI = \frac{\sum R(i,j) - R(i-1,i+1)}{\sum I(i,j) - I(i-1,i+1)}$$

The highest value of EEI is 1, and the best edge preservation occurs at a high score of this metric.

## 2. Methods

### A. Local Adaptive Median Filter (LAMF)

Local Adaptive Median Filter (LAMF) was successfully applied to the SAR image by Qiu. (2004). LAMF detects speckle noise based on analysis of the statistical properties of the candidate pixel at different window sizes (3x3, 5x5 and 7x7), then swap outlier pixel (speckle noise pixel) with the valid pixel. However, in this work LAMF was modified and applied on the musculoskeletal ultrasound image with more expanded windows (3x3, 5x5, 7x7, 9x9 and 11x11) to examine the impact of enlarging dimensions of sliding window on the speckle pixels detection. Evaluation of statistical properties and entropy within small window includes local mean and standard deviation determination, see figure (1).



**Figure 1.** flow representation of the processing steps when applying LAMF on 3x3 mask (central pixel and its neighbours around the image).

### 1- Detection of the speckle pixels of the input image

Each pixel in the input image was examined whether it is speckle or valid pixel. Detection of the pixels was performed by evaluating the statistics (local mean, local standard deviation and local entropy) of the sliding window across input image. Equations (8), (9), (10) and (11) give lower and upper border detection of each pixel inside the image.

$$(8) \quad LB(i, j) = \mu(i, j) - f * \sigma(i, j)$$

$$(9) \quad UB(i, j) = \mu(i, j) + f * \sigma(i, j)$$

$$(10) \quad LE(i, j) = ((e(i, j) * f) - 1) * c(i, j)$$

$$(11) \quad UE(i, j) = ((e(i, j) * f) + 1) * c(i, j)$$

where  $\mu$  is local mean,  $\sigma$  is local standard deviation,  $e$  is local entropy of the selected window, dimensions of the central pixel are  $(i, j)$  and  $f$  is controlled factor. Speckle and valid pixels are labelled by moving the window (central pixel is  $c(i, j)$ ) and detected pixel is  $d(i, j)$ . Equation (12) illustrates the condition of detection the central pixel whether it is a valid pixel or speckle pixel.

Equation (12):

$$\begin{aligned} d(i, j) &= 1 & \text{if } LB(i, j) \leq c(i, j) \leq UB(i, j) \\ d(i, j) &= 1 & \text{if } LE(i, j) \leq c(i, j) \leq UE(i, j) \\ d(i, j) &= 0 & \text{if } c(i, j) < LE(i, j) \text{ or } c(i, j) > UB(i, j) \\ d(i, j) &= 0 & \text{if } c(i, j) < LB(i, j) \text{ or } c(i, j) > UE(i, j) \end{aligned}$$

### 2- Replace speckle pixel with valid pixel

After tracking and detection speckle pixels using equation (12), modified local median filter is applied on the selected window, which contains speckle pixel as the central pixel in the windows. This means, the replacement depends on the evaluation of the local median filter by swapping detected speckle pixel with median value of the window. The primary purpose of that is to reduce the impact of speckle noise on the image. However, reducing noise using a median filter is affected by two factors: the spatial content of the neighbourhood and the number of pixels which are utilized in the evaluations.

### 3. Experimental and Results

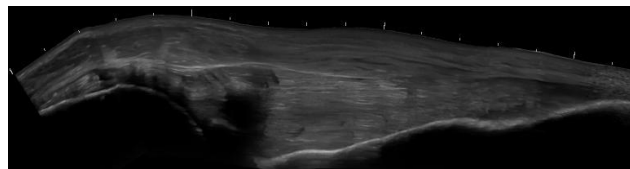
In this work, three experiments were performed; the first experiment was applied on five samples, which were collected from the right shoulder of the cadaver [21]. On the other hand, the other two experiments were obtained from healthy volunteers from forearm (longitudinal section of triceps muscle) and hand (transverse section of Flexor Pollicis longus tendon) [4], each experiment has five samples.

Before performing modified LAMF (LAMF2), the most appropriate window size was selected based on a high score of assessment metrics of speckle noise reduction. Implementation of LAMF2 was achieved using equation (8-12), control parameter  $f$  was 1.5 (used in the speckle noise reduction of SAR image [12], also it was used in the musculoskeletal ultrasound imaging. If the value of  $f$  is greater than 1, it is possible to detect many speckle pixels but, in other cases can keep many valid pixels in the output image. The proposed algorithm was tested both numerically and experimentally.

#### Experiment 1

##### Cadaver image sample

LAMF2 was carried out on the cadaver ultrasound image sample, shown in figure (2), using different window sizes (3x3, 5x5, 7x7, 9x9 and 11x11).



**Figure 2.** the first sample of musculoskeletal ultrasound image, which was collected from cadaver (right shoulder region).

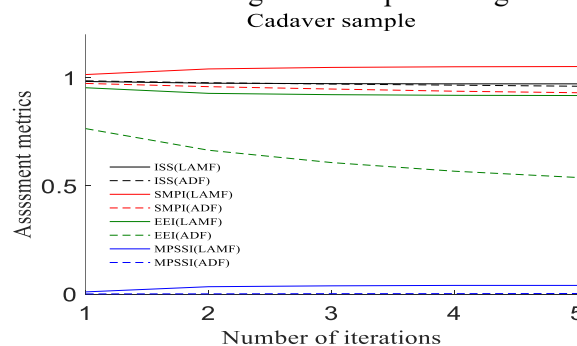
The following table illustrates the evaluation the mean value of the assessment metrics (SSI, SMPI, EEI and MPSSI) on the five image samples after applying LAMF1 and LAMF2, figure (2) represent the first sample. This assessment was performed on different window sizes, see table (1).

Table (1), Evaluation of assessment metrics of cadaver musculoskeletal ultrasound image samples (mean value of five samples), after applying LAMF1 and LAMF2.

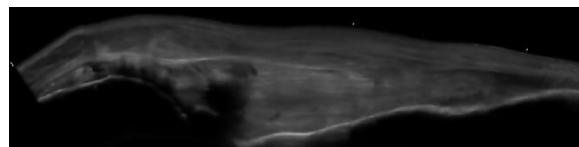
Selected window	Filters	Metrics			
		SSI	SMPI	EEI	MPSSI
3x3	LAMF1	0.972	1.052	0.918	0.0004
	LAMF2	0.991	1.000	0.999	0.0003
5x5	LAMF1	0.973	1.105	0.881	0.005
	LAMF2	0.959	1.102	0.900	0.0048
7x7	LAMF1	0.968	1.147	0.881	0.008
	LAMF2	0.960	1.150	0.885	0.009
9x9	LAMF1	0.953	1.188	0.890	0.0106
	LAMF2	0.941	1.970	0.888	0.022
11x11	LAMF1	0.924	1.564	0.727	0.027
	LAMF2	0.923	1.600	0.788	0.029

It is clear from the table (1), the performance of LAMF2 outperforms LAMF1. Moreover, window 3x3 gives lower scores of SSI, SMPI and MPSSI and a high score of EEI compared with other window sizes for both filters. Therefore, LAMF2 is carried out at window size 3x3 and compared with the performance of ADF at this window and the process was repeated five times (five iterations). The purpose of iterations is to repeatedly apply the same process to the output at each pass. This is so systematically increasing the effect of the filter, rather than to evaluate the output.

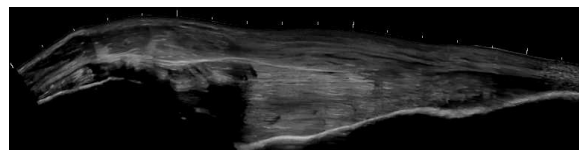
Figure (3), illustrates the comparison between two filters using four assessment metrics (ISS, SMPI, EEI and MPSSI). Whereas, figure (4) and figure (5) show the output image after applying ADF and LAMF2 on the image in figure (2) respectively. Figure (4) shows EEI metrics of LAMF with a higher score than EEI metrics of ADF. Furthermore, it is possible to observe in the figure (5), many of the edge pixels in the original image are retained in the filtered image compared with figure (4), which illustrates many homogenous regions in the filtered image and less preserving of the image edges.



**Figure 3.** Comparison between performance of LAMF2 and ADF across five iterations when performing on cadaver musculoskeletal ultrasound image and window size is 3x3.



**Figure 4.** Cadaver musculoskeletal ultrasound image of the first sample after applying ADF.



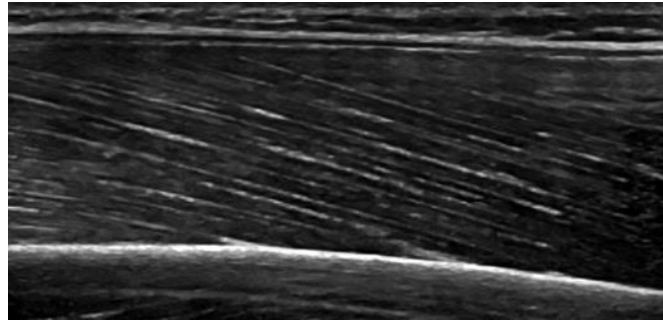
**Figure 5.** Cadaver musculoskeletal ultrasound image of the first sample after applying LAMF2.

This experiment helps to apply two different filters on the musculoskeletal cadaver image to reduce speckle noise and get an enhanced image.

## Experiment 2

### Healthy image samples (longitudinal section of triceps muscle)

In the previous experiment, cadaver image sample is used to get evidence for illustration of the performance of two filters (LAMF1 and LAMF2). For more applications, healthy image samples were used. Healthy image samples (5 samples) were collected from triceps muscle (longitudinal section), figure (6) illustrates the first sample.



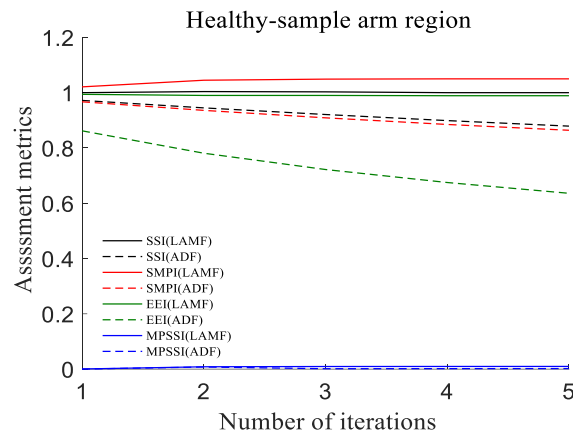
**Figure 6.** Healthy musculoskeletal ultrasound image (the first sample of triceps ultrasound image).

Following the same steps of the cadaver samples, the performance of LAMF1 was compared with LAMF2; a window size was selected numerically. Table (2) presents calculation of four metrics assessments (mean value) of five image samples after applying LAMF's filters and at different window sizes (3x3, 5x5, 7x7, 9x9 and 11x11), figure (6) shows the first sample. From this table and based on the assessment metrics, window 3x3 shows that it is the most suitable window, which is used in performing LAMF's filters. Therefore, the performance of ADF compared with LAMF2 at this window is shown in the figure (7). Furthermore, figure (8)a and figure (8)b illustrate the output images after performing ADF and LAMF2 on the image in figure (6) respectively. Based on the figure (8a) and through figure (8b), the same conclusion of the previous experiment (using cadaver image sample) was obtained.

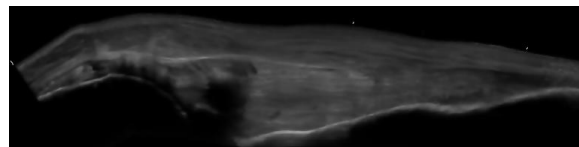
**Table 2.** Evaluation of assessment metrics of arm musculoskeletal ultrasound image samples (mean value of five samples) , after applying LAMF1 and LAMF2.

Selected window	Filters	Metrics			
		SSI	SMPI	EEI	MPSSI
3x3	LAMF1	0.990	1.05	0.989	0.0009
	LAMF2	0.960	1.008	1.00	0.0007
5x5	LAMF1	0.993	1.228	0.967	0.005
	LAMF2	0.98	1.212	1.00	0.004
7x7	LAMF1	0.953	1.722	0.955	0.018
	LAMF2	0.930	1.899	0.97	0.010
9x9	LAMF1	0.901	2.108	0.956	0.029
	LAMF2	0.877	2.00	0.966	0.022
11x11	LAMF1	1.448	11.35	0.644	0.212
	LAMF2	1.445	8.66	0.628	0.124

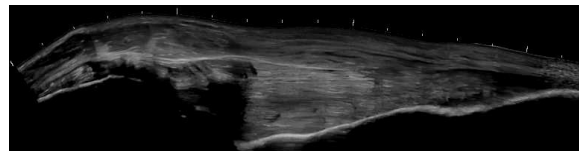




**Figure 7.** Comparison between performance of LAMF2 and ADF across five iterations when performing on cadaver musculoskeletal ultrasound image and window size is 3x3.



**Figure 8.** Cadaver musculoskeletal ultrasound image of the first sample after applying ADF.



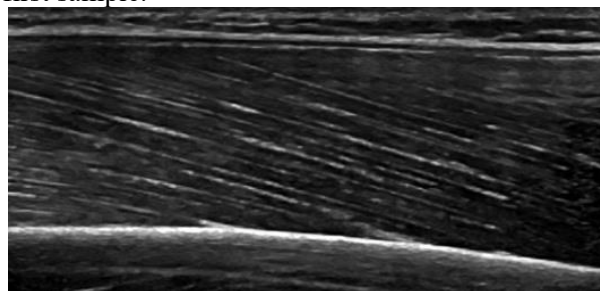
**Figure 9.** Cadaver musculoskeletal ultrasound image of the first sample after applying LAMF2.

This experiment helps to apply two different filters on the musculoskeletal cadaver image to reduce speckle noise and get an enhanced image.

## Experiment 2

### Healthy image samples (longitudinal section of triceps muscle)

In the previous experiment, cadaver image sample is used to get evidence for illustration of the performance of two filters (LAMF1 and LAMF2). For more applications, healthy image samples were used. Healthy image samples (5 samples) were collected from triceps muscle (longitudinal section), figure (10) illustrates the first sample.

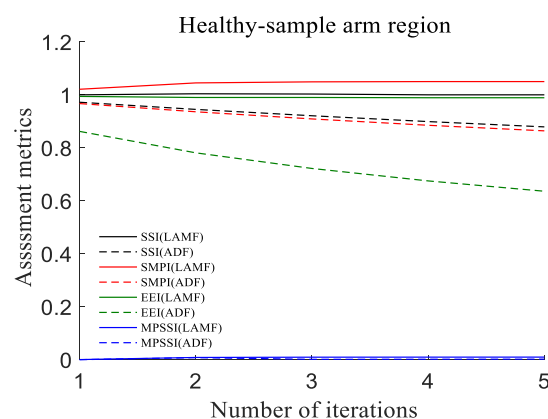


**Figure 10.** Healthy musculoskeletal ultrasound image (the first sample of triceps ultrasound image).

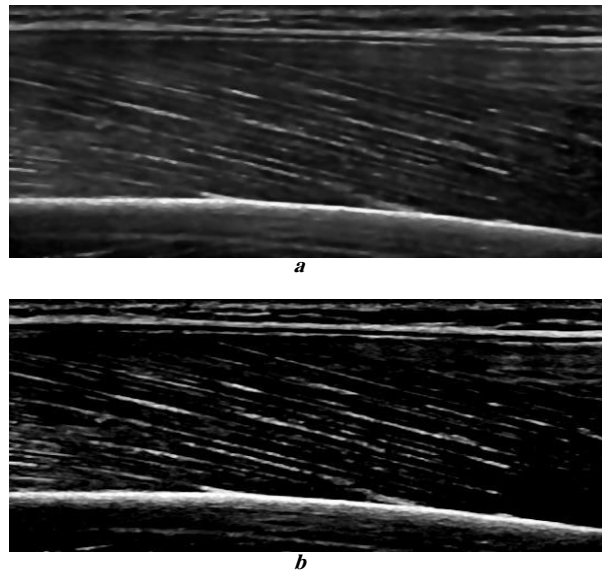
Following the same steps of the cadaver samples, the performance of LAMF1 was compared with LAMF2; a window size was selected numerically. Table (3) presents calculation of four metrics assessments (mean value) of five image samples after applying LAMF's filters and at different window sizes (3x3, 5x5, 7x7, 9x9 and 11x11), figure (11) shows the first sample. From this table and based on the assessment metrics, window 3x3 shows that it is the most suitable window, which is used in performing LAMF's filters. Therefore, the performance of ADF compared with LAMF2 at this window is shown in the figure (12). Furthermore, figure (13)*a* and figure (8)*b* illustrate the output images after performing ADF and LAMF2 on the image in figure (7) respectively. Based on the figure (8a) and through figure (8b), the same conclusion of the previous experiment (using cadaver image sample) was obtained.

**Table 3.** Evaluation of assessment metrics of arm musculoskeletal ultrasound image samples (mean value of five samples) , after applying LAMF1 and LAMF2.

Selected window	Filters	Metrics			
		SSI	SMPI	EEI	MPSSI
3x3	LAMF1	0.990	1.05	0.989	0.0009
	LAMF2	0.960	1.008	1.00	0.0007
5x5	LAMF1	0.993	1.228	0.967	0.005
	LAMF2	0.98	1.212	1.00	0.004
7x7	LAMF1	0.953	1.722	0.955	0.018
	LAMF2	0.930	1.899	0.97	0.010
9x9	LAMF1	0.901	2.108	0.956	0.029
	LAMF2	0.877	2.00	0.966	0.022
11x11	LAMF1	1.448	11.35	0.644	0.212
	LAMF2	1.445	8.66	0.628	0.124



**Figure 11.** Comparison between performance of LAMF2 and ADF across (1-5) iterations when performing on the healthy sample of the musculoskeletal ultrasound image (triceps muscle) and the size of the window is 3x3.

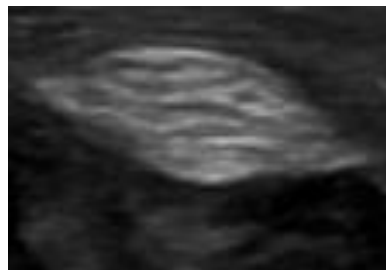


**Figure 12.** Healthy musculoskeletal ultrasound image (the first sample of triceps ultrasound image after applying ADF is shown in figure (a), while figure (b) illustrates output image after applying LAMF2).

### Experiment 3

#### Healthy image samples (hand region)

Another Healthy image sample were collected from ultrasound scanning of the hand region (transverse section of Flexor Pollicis longus tendon) as shown:



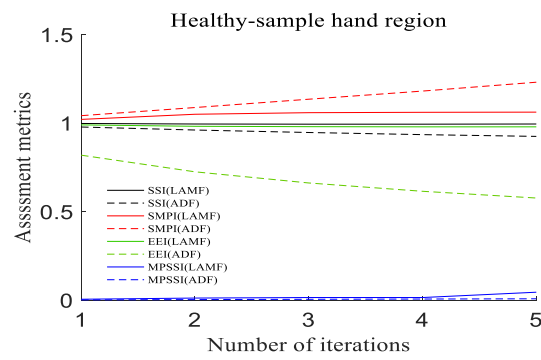
**Figure 13.** Healthy musculoskeletal ultrasound image (the first sample of cross section of flexor pollicis longus tendon).

The same results of the previous healthy sample (longitudinal section of triceps muscle): window 3x3 is the most suitable window for both filters (LAMF1 and LAMF2), and ADF outperforms in the speckle noise reduction, while LAMF has more ability in the edge preservation, see table (4) and figures (10) and (12a-b) below.

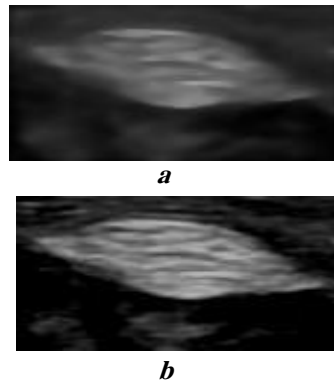
**Table 4.** Evaluation of assessment metrics of hand musculoskeletal ultrasound image samples (mean value of five samples), after applying LAMF1 and LAMF2.

Selected window	Filters	Metrics			
		SSI	SMPI	EEI	MPSSI
3x3	LAMF1	0.944	1.062	0.979	0.001
	LAMF2	0.998	1.000	1.000	0.003

5x5	LAMF1	0.849	1.479	0.899	0.012
	LAMF2	0.986	1.400	0.999	0.023
7x7	LAMF1	0.896	1.776	0.804	0.028
	LAMF2	0.768	1.675	0.848	0.019
9x9	LAMF1	0.700	1.4521	0.967	0.0013
	LAMF2	0.891	1.322	1.000	0.0019
11x11	LAMF1	0.776	1.954	0.767	0.0028
	LAMF2	0.870	1.533	0.79	0.0022



**Figure 14.** Comparison between performance of LAMF2 and ADF across (1-5) iterations when performing on cadaver musculoskeletal ultrasound image.



**Figure 15.** Healthy musculoskeletal ultrasound image (cross section of flexor pollicis longus tendon) after applying ADF is shown in figure (a), while figure (b) illustrates output image after applying LAMF2.

Speckle noise was reduced in two different healthy image samples using ADF and LAMF's filters. The enhanced musculoskeletal ultrasound images will support extraction of musculoskeletal parameters based on musculoskeletal ultrasound image of an individual.

#### 4. Discussion

Speckle noise during the recording of the musculoskeletal ultrasound images is the major confounder that was reported in the previous studies [4], [10]. It degrades the fine details of the ultrasound image and effects on the image quality. The existence of speckle noise in an ultrasound images is mostly connected to the complex interactions of the coherent ultrasound signal, which can be captured as a part of the image acquisition process of an ultrasound machine.

In this work, the Local Adaptive Median Filter (LAMF) was modified and applied on the 15 samples of the musculoskeletal ultrasound images. In this work, local statistical tools (mean and standard deviation) and local entropy have been recruited to recognize speckle pixels from valid pixels. After that these valid pixels have been kept and speckle pixels are replaced using local median filter.

The performance of local adaptive median filter in all musculoskeletal ultrasound images shows a tendency to increase when using window size 3x3 compared with other window sizes (3x3, 5x5, 7x7, 9x9 and 11x11) to see any differences through increasing image details across window size, see tables (1-3) and table (4) below.

From table (4), the window size (3x3) demonstrates a higher quality of speckle noise reduction compared with other window sizes. Therefore, 3x3 was chosen as a more suitable size for the performance of LAMF2. The iterations are stopped when there is no significant change in the quality of speckle noise reduction. The performance of local adaptive median filter decreases when increasing the number of iterations; therefore, five iterations were chosen to show the behaviour of performance of this filter across several times of performing. One thing worth noticing from figure (5), figure (8) and figure (11) is that the performance of the local adaptive median filter did not improve with increasing window size and number of iterations. Anisotropic Diffusion Filter (ADF) was utilized in this work to reduce the impact of the speckle noise on musculoskeletal ultrasound images to compare with LAMF2 on the same samples of these images at window size 3x3.

In the case of 3x3 window size and using ADF, the ultrasound image samples, which were collected from a cadaver and healthy triceps muscle had a high level of performance regarding speckle noise reduction (see figure (4) and figure (8)). On the other hand, the edge preservation reported high scores in all three-different samples using LAMF2; see figure (4), figure (8) and figure (11). These results indicate that performance of ADF is better in speckle noise reduction, while LAMF2 outperforms ADF in edge preservation.

**Table 4.** percentage of assessment metrics for different window sizes (3x3, 5x5, 7x7, 9x9 and 11x11). The percentage presents mean value of three experiments after applying LAMF1 and LAMF2.

Selected	Metrics			
	SSI	SMPI	EEI	MPSSI
w	LAMF2<	LAMF2<	LAMF2>	LAMF2<LAMF1
i	l	L	L	
n	.	A	A	
d	l	M	M	
o	l	F1	F1	
w	.			
3x3	3%	4.79%	3.7%	40%
5x5	1.68%	3.2%	1.3%	32%
7x7	1.81%	3.46%	1.8%	32.5%

9x9	0.9%	2.11%	1.4%	11.11%
11x11	2.77%	2%	2.5%	2%

## 5. Conclusions

It is difficult to eradicate speckle noise from ultrasound image completely because it is multiplicative noise. However, the results obtained show superior performance of LAMF2 compared with LAMF1. Furthermore, there is a competitive performance between the two filters (LAMF2 and ADF) in despeckling musculoskeletal ultrasound images. ADF is better than LAMF2 in speckle noise reduction, but with less ability in the preservation of the image edge. This could cause a trade-off between noise suppression and delineation of features of the image, where ADF having superior ability in speckle noise reduction compared with LAMF filters.

It is possible to involve developed local adaptive median filter in the further applications such as medical image analysis. One of these applications is using enhanced musculoskeletal image in the measurement of geometric parameters such as tendon length, cross-section area and circumference.

## References

- [1] Sanches, J. M., Nascimento, J. C. and Marques, J. S. (2008). Medical Image Noise Reduction Using the Sylvester-Lyapunov equation. *IEEE Transactions on image processing*, 17(9), 1522–1539.
- [2] Binaee, K., and Hasanzadeh, R. P. R. (2014). An ultrasound image enhancement method using local gradient based fuzzy similarity, *Biomedical Signal Processing and Control*. 13, 89–101. doi: 10.1016/j.bspc.2014.03.013.
- [3] S. I. Jabbar, C. R. Day and E. K. Chadwick, " Enhancement of Panoramic musculoskeletal Ultrasound Image based on Fuzzy Technique" in *2019 ACM, ICICT2019 Proceeding of the International Conference on Information and Communication Technology*, Baghdad, 2019, pp. 228-232.
- [4] S. I. Jabbar, C. R. Day and E. K. Chadwick, "Using Fuzzy Inference system for edge detection of musculoskeletal ultrasound images," in *IEEE Conference on Fuzzy Systems, FUZZ-IEEE'19, 2019 FUZZIEEE*, Florida, USA, 2019.
- [5] Perona, P. and Malik, J. (1990). Scale-space and edge detection using anisotropic diffusion. *IEEE Trans. on Pattern Analysis and Machine Intelligence*. 12(7), 629–639.
- [6] Aja-Fernandez, S. and Alberola-Lopez, C. (2006). On the estimation of the coefficient of variation for anisotropic diffusion speckle filtering. *IEEE Transaction in image processing*. 15(9), 2694–2701.
- [7] Abd-Elmoniem, K.Z., Youssef, A.B.M. and Kadah, Y.M. (2002). Real-Time Speckle Reduction and Coherence Enhancement in Ultrasound Imaging via Nonlinear Anisotropic Diffusion. *IEEE Transactions on Biomedical Engineering*. 49(9), 997–1014.
- [8] Bama, S. & Selvathi, D. (2014). Despeckling of medical ultrasound kidney images in the curvelet domain using diffusion filtering and MAP estimation. *Signal Processing*. 103, 230–241. Available at: <http://dx.doi.org/10.1016/j.sigpro.2013.12.020>
- [9] Krissian, K., Westin, C.F., Kikinis, R. and Vosburgh, K.G. (2007). Oriented Speckle Reducing Anisotropic Diffusion. *IEEE Transaction on Image Processing*. 16(5), 1412-1424.
- [10] Gupta R., Elamvazuthi I., Dass S., Faye I., Vasant P., George J., and Izzo F. (2014). Comparative Analysis of Anisotropic Diffusion and Non- Local Means on Ultrasound Images. *Journal of Machine to Machine Communications*. 1(1), 51–68
- [11] Michailovich, O. V & Tannenbaum, A. (2006). Despeckling of Medical Ultrasound Images. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control transactions on Ultrasonics, ferroelectrics, and frequency control*. 53(1), 64–78.
- [12] Koundal, D., Gupta, S. and Singh, S. (2015). Speckle reduction method for thyroid ultrasound images in neutrosophic domain, *IET Image Processing*, 10, (2), pp. 1-9.
- [13] Qiu, F., Berglund, J., Jensen, J.R., Thakkar, P. and Ren, D. (2004). Speckle Noise Reduction in

- SAR Imagery Using a Local Adaptive Median Filter. *GIScience and Remote Sensing*. 41(3), 244–266.
- [14] Tizhoosh, H. R., Krell, G. and Michaelis, B. (1997). On Fuzzy Enhancement of Megavoltage Images in Radiation Therapy. *IEEE Conference on Fuzzy Systems, FUZZ-IEEE'97*. 3, 1399–1404.
- [15] Perona, P. and Malik, J. (1990). Scale-space and edge detection using anisotropic diffusion. *IEEE Trans. on Pattern Analysis and Machine Intelligence*. 12(7), 629–639
- [16] Grieg, G., Kubler, O., Kikinis, R. and Jolesz, F. A. (1992). Nonlinear Anisotropic Filtering of MRI Data. *IEEE Transactions on Medical Imaging*. 11(2), 221–232.